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Mission Debriefing System

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Abstract

Systematic has developed a debriefing system for aircraft crews to improve their skills based on experiences from completed missions. The system is developed on Commercial Off The Shelf (COTS) software and on a PC. The panel should see this input as a portable, low-cost Virtual Reality (VR) training system for aircraft crews. The benefit of the portability is that the system can be **used anywhere** the unit is deployed and **by any crewmember.**

Flight hours are rather expensive and therefore the air forces must maximise the benefits from spent flight hours. This, combined with the fact that most air force units need to operate from different deployments remote from home bases, led the operational fighter squadrons to express a need for a low-cost debriefing system.

The users were directly involved in the design and the focus was set on functionality — not technology. This approach has resulted in a system which gains accept among users and therefore becomes an everyday training tool. Driven by user requirements, the system is developed to run on a Microsoft Windows 2000 platform, and the system can interface with other systems. Furthermore, it has been essential to develop a system, which could be rapidly implemented.

The debriefing system uses already existing information from the aircraft. The aircraft is equipped with Global Positioning System (GPS), three video cameras, and a microphone system to record the pilot's voice communication. The video cameras record the pilot's view through his head-up display and the entire instrument panel.

Prior to the debriefing session all information from the aircraft (GPS-data, video- and audio recordings) is fed into the debriefing system. The GPS-data is loaded into a three dimensional (3D) model containing geographical information, the video and audio recordings are digitised, and all data are synchronised. On each monitor, four visual sources can be displayed concurrently, e.g. video recordings from three different aircraft and the graphical 3D view of the area, including aircraft. The selected visual sources are displayed along with a selected audio recording. The 3D graphic makes it possible to see and follow selected aircraft from different perspectives on their mission. Furthermore, it is possible to see them chase other aircraft and to track their route by position, direction, and speed. The crew and other mission participants can by themselves prepare and execute the debriefing session.

Systematic has developed a portable, low-cost VR training system for aircraft crews, which converts reality to virtual reality, reflecting the reality. The chosen approach, with heavy user involvement, has resulted in a system, which is easy to use and will gain much better acceptance. A system based on well-proven COTS products reduces costs as well as risks. Finally, the system gives added value to the flight hours spent.

Introduction

It is our aim with this paper to disseminate understanding for the possibilities given by new commercial off the shelf (COTS) products — in this case especially for low cost virtual reality training tools. We find that today's COTS software fulfils most of the requirements that the military has to an everyday debriefing system. By combining the COTS products using Systematic's competence in software integration, a low-cost easy-to-operate operational training system, has been developed.

Through this paper, we discuss functional requirements, use of commercial state of the art technology, influence on training and human performance requirements, and describe the development process and functionality in our debriefing system.

In connection with the training of combat pilots much time is spent on manoeuvres in actual air combat techniques. The Danish Air Force spends more than half of the flight hours on such manoeuvres. Furthermore, the remaining flight hours often contains elements of air combat. It is therefore essential to get full benefit from the training, especially as flight hours are extremely costly. Nevertheless, subsequent debriefing and evaluation of a training session is often deficient or non-existing.

The present project has endeavoured to remedy this inadequacy by investigating the possibilities for building an inexpensive, simple and user-friendly, but yet high-tech, mission debriefing system, for "everyday use". We have used virtual reality (VR) and 3D techniques for

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constructing factual conditions for training in a Virtual Environment (VE). The VE facilitates the debriefing of pilots and thereby enhances the learning. Presently the system is developed as a 1. generation version with basic functionality financed by our company. We find though, that the idea has much potential, and we will promote our ideas broadly within NATO.

Background

Security in the Euro-Atlantic area has substantially improved during the 1990s, by comparison with the four decades that preceded them. The threat of massive military confrontation has gone, and co-operative approaches to security have replaced former confrontation. Nevertheless potential risks to security from instability or tension still exist.

In these changed circumstances affecting Europe's security, NATO forces have been adapted to the new strategic environment and have become smaller and more flexible. Conventional forces have been substantially reduced and in most cases so has their level of readiness. They have also been made more mobile, to enable them to react to a wider range of contingencies; and they have been reorganised to ensure that they have the flexibility to contribute to crisis management and to enable them to be built up, if necessary, for the purposes of defence. Increased emphasis has been given to the role of multinational forces within NATO's integrated military structure. Many such measures have been implemented. Others are being introduced as the process of adaptation continues.

Airforces are characterised by their ability to operate from far distance, geographically dispersed bases and concentrate their efforts against the main targets. They are also able to react very fast and to maintain a high degree of readiness. These characteristics have made airforces even more important to NATO's new strategic concept, Combined Joint Task Forces (CJTF). The main issue in this concept regarding air forces is high readiness, interoperability and the ability to operate away from home bases with a minimum of preparations. Furthermore each participating unit must be able to perform a larger variety of roles, than before — e.g. using heavy bombers for close air support. The operational environment has become much more dynamic — it is never possible to foresee which type of operation that will turn up. This again puts higher demands on continuous and flexible training.

Another consequence of the new operational environment is the reduced military budgets. This means that it is essential to gain as much as possible from the applied training efforts. In real operations like Allied Force in Kosovo last year, it is extremely important that the pilots learn from each mission to make continuos improvements. In this specific example, most of the participating units operated far away from home bases. Therefore they were not able to take advantage of their usual static training equipment and simulators.

Project Objectives and Means

An obvious need for mobile training, rehearsal and debriefing systems has evolved. Given the fast development within virtual reality technology and low cost flight simulators for PCs, we have seen a good opportunity to use commercial technology and existing sensors, video recordings, and tapes from the aircraft to develop a debriefing system for air force pilots.

The overall objective was to create a low cost, easy-to-operate, and transportable debriefing system. With this objective the intention was that each training session and live mission should be followed up by a high-quality debriefing activity, giving full benefit of the costly flying time to the pilots.

The aim was to base the system on COTS products and existing and electronically available data from the aircraft. Furthermore, the aim was to combine the collected data from the aircraft and thereby constitute a 3D Virtual Reality (VR) replay of the completed missions and training sessions.

The project is financed by Systematic and the ingredients used are Systematic's skills and knowledge, technologically as well as military, a range of COTS products, and the requirements set by airforce pilots.

System requirements and functionality

This section describes the scenarios and missions that are supported by the debriefing system. To stress out the need for a debriefing system, we give a brief description of the main categories of existing systems.

Air Combat Manoeuvring (ACM)

Air combat comprises all kinds of manoeuvres in the air in a one-to-one, many-to-one or many-to-many situation. ACM includes all the classical movement patterns such as half loop, full loop, split S, break turn etc. Basically, air combat is a question of gaining the right position in relation to the opponent.

A training session consists of a number of scenarios, ranging from 3 to 10 — depending on the number of fighters involved. A scenario lasts from 5 to 10 minutes. The starting point of a scenario is an initial position where, for example, the different players have got radar contact (approx. 30NM distance). Typically, the situation then develops rapidly, depending on the actions that take place during the session. After only a few minutes, the situation typically becomes very complex and the pilots often lose control of the situation. As an example, a pilot who tries to escape will lose control of what is going on, as he has no longer radar contact with the other fighters.

When a training session is over, the pilots involved should evaluate the session. This is typically a difficult process, partly because the individual sessions develop in a complex way where each pilot may have different opinions on what actually happened, if they are able to contribute to the situation at all. But also because the individual scenarios become indistinguishable when the pilots have returned to the air base. As a result hereof, debriefing is deficient or non-existing. Consequently, much value of the training is lost. This should be viewed against the large resources spent on keeping the fighters in the air.

Existing Solutions (ACM)

In order to enhance the debriefing possibilities, various systems are available for the pilots for recreating the individual scenarios that constituted the training. Generally speaking two solutions exists: A low-cost and an expensive solution.

Low-Cost Solution: Video

The F-16 fighters used by the Danish Air Force are equipped with three standard video cameras, which records the Head Up Display (HUD) and the two Multi Function Displays (MFD). The pilots can use these videos in a subsequent debriefing. Videos are excellent for the initial scenario and evaluation of shootings. In a debriefing situation, the pilots involved will endeavour to recreate the individual scenarios in the training session. If the pilot has lost control, however, videos are of little use (the radar image may be of no value). Furthermore, it is difficult and time-consuming to synchronise multiple videotapes and ECM as well as kill removal are not covered by video at all.

The Expensive Solution: Real-time ACM Instrumentation (ACMI)

Real-time ACMI covers the expensive and extensive solution where the individual fighters that participate in the session downlink information in real-time to a control station on the ground. Via the control station, the individual scenarios are monitored and stored for later debriefing. The control station may even intervene during the training session, either in order to influence the situation in a certain direction or due to kill removal.

Real-time ACMI involves pod-mounted electronics (GPS, MUX-BUS interface and data link) as well as antenna coverage on the ground and all control facilities on the ground. Consequently, the solution is quite costly in terms of electronic equipment and staffing, and ACMI will not become a natural part of every training session. ACMI must be planned a long time in advance and will only be used few times a year.

Systematic's mission debriefing system

Based on informal discussions with both pilots from Air Station Ålborg and the Danish Air Materiel Command, we have developed a first generation model to show the possibilities.

The first generation of the debriefing system is an autonomous system and does not require any changes in the cockpit or instrumentation of the aircraft. The system is centred on a debriefing facility, based to the greatest possible extent on COTS hardware and software.

The debriefing system uses already existing information from the aircraft, the Global Positioning System (GPS) data, the three videos (HUD and 2xMFD), and a recording of pilots' voice communication.

The HUD, MFD, voice recording, and GPS data of the individual aircraft are loaded into a Personal Computer (PC), which synchronises the data. From the synchronised data the PC constructs a 2D/3D synthetic world of "what happened".

The three videotapes and the voice recording are used to give a detailed image of the pilots' actions, displaying what happened inside the cockpits. The GPS data from all aircraft are loaded into a 3D model of the battle cube. The 3D model does, just like a Geographical Information System (GIS), contain a 3D graphical model of the landscape in the battle cube. This 3D model of the landscape combined with the aircraft GPS data gives a "Gods eye view" of the battle cube. The debriefing system makes it possible to navigate around in the battle cube. This makes it possible to view the scenery from different perspectives.

All aircraft that can provide the information described above can be included in the debriefing session. Consequently, the system can be used not only by the Royal Danish Air Force's F-16 fighter pilots. Furthermore, a debriefing system like this can be used independently of the geographical location and extension of the individual training sessions. Compared with the real-time ACMI system, this provides an obvious advantage; the real-time ACMI system is not mobile, but limited to the location that is covered by the antenna equipment of the ground station.

The latest techniques in Virtual Reality and 3D have been investigated in connection with the construction of the synthetic world. These areas undergo extensive research and development within the experimenting field of computer science, and are consequently considered to contain some of the building blocks for the future development within HCI (Human Computer Interaction). The debriefing system includes leading edge technologies within these fields. It is our aim to present a system that will delight and motivate the pilots to carry out high-quality debriefing.

Development of the debriefing system

This section is a brief description of our approach to the project. Based on our interviews with potential users, a retrieval of user requirements and a study of existing COTS products and their facilities, we started the development process. Knowing that we had to do with new technology, it was essential for us to study and develop small prototypes of the different functionalities in the system. We decided to break the system into three main subsystems, which were to be developed and tested sequentially. The initial aims were:

- To see if we could develop 3D graphics using "cheap" COTS technology and already available data.
- To test the different 3D graphical components/effects that we wanted to make use of.
- To establish a 3D-terrain model, which was suitable for debriefing purposes.
- To establish a user-friendly interface and the framework from which the debriefing application should be prepared and presented.

In the following text we describe each of the initial prototypes, it's purpose, the method used to develop it and the result/experiences gained.

Prototype 1

This part resulted in a 3D-terrain model with a visualisation of a number of aircraft including their tracks, so that one can get an overall view of the full mission or extracted parts of a mission or flight.

Purpose

- To get a 3D-terrain model and to show it on a PC (We decided to get the necessary data from the Danish F-16 simulator).
- To make a 3D visualisation of aircraft (including their historical tracks).
- To create lively navigation and animation methods (the aircraft should be able to manoeuvre and navigate in a realistic way so that an aircraft would bank naturally when turning and so forth).
- To enable the user to choose between different angles of view (e.g. "God's-eye-view").
- To visualise other objects (e.g. Surface to Air Missile sites with threat domes).
- Portability: To be able to port the system between the normal PC platform and a more static SGI graphical supercomputer with holobench.

Method

In brief we have had a very open and innovative approach where following main activities were carried out:

- Information search on the Internet to get components and pieces of code, which could be useful.
- Selection of a portable visualisation core component. (Optimizer™ from Silicon Graphics).
- Courses in the use of Optimizer™.
- Prototyping and test using visualisation methods and navigation.
- Get inspiration through the studies of existing ACMI systems.
- Initial development on PC — later ported to SGI.

Results

These were the results we got from our first developments:

- Functionality to convert the database from the F-16 MLU simulator to "PC-format".
- A prototype application showing a landscape of size 10 x 10 NM.
- Playback of flights. (Specifically two flights flying different routes.)
- Possibility to see the flights in a follow-mode (seen from one of the flights or in a "God's-eye-view").
- Portability between PC and SGI (holobench).
- Possibility to run the application on a PC with a powerful graphics card.

Prototype 2

The next step was to develop an application that could visualise a complete geographical database and to make 3D movement through the landscape.

Purpose

- To create functionality to visualise a complete geographical database covering a normal theatre of operations.

Method

- Use experiences from prototype 1.
- To develop and implement efficient methods to get and drop tiles of terrain in the visible area.
- To convert the F-16 MLU simulator database to PC-format".

Results

- A prototype 2 application with functionality, which in principle (if terrain data is available) can show any given terrain.
- Geographical data enabling the system to cover Denmark and Southern Norway.
- This prototype was only developed for a PC.

Prototype 3

The third prototype is the set-up and administration tool, developed on a Microsoft Outlook user interface.

Purpose

- To obtain functionality to administrate flights and missions. (A flight is an operation/flying session performed by one aircraft and a mission is a combination of concurrent flights).
- To be able to perform video playback.
- To synchronise video inputs and the 3D-terrain model.
- To present a graphical user interface (GUI) for debriefing and administration in a Microsoft Outlook view.

Method

- Standard components were to be used
  - Standard Template Library (STL) from Silicon Graphics.
  - Microsoft Foundation Classes (MFC) from Microsoft.
  - Windows media standard components for video playback.
  - Microsoft Access Database.
- Use of simple application development (Visual C++, 6.0).
- Use of well-known components for the GUI (Microsoft Outlook).

Results

- A quad-view (four concurrent views on same screen) with an intuitive timeline that permits playback, review, pause etc.
- An intuitive, easy-to-learn GUI.
- Use of Windows standard functionality to synchronise video and data.

Integration to a first generation model

Before integration of the three prototypes into the first generation of debriefing system, we had to solve some minor problems that occurred during test of prototypes:

- Geographical data are extensive and requires a harddisk of at least 1GB for the database. We improved our hardware to the necessary level.
- Movements through the 3D terrain require loading and initialising of huge amounts of data. Therefore a dual processor system and a very fast harddisk must be used to give video and other resources enough processing power.
- Using video and 3D-graphics in the same session creates performance problems — Windows 2000 combined with multiple graphic cards solves the problem.

Once these problems were solved we were able to load the real, digitised video from F-16 aircraft and through prototype 3 we could initiate, administrate and run the debriefing system with the introduced functionality. The result is promising and after some pre-tests with real users and the necessary adjustments and improvements in functionality a flexible system is ready to be implemented with operational fighter squadrons.

Use of Systematic's debriefing system

Using the Systematic debriefing system is a 3-step process:

- Digitisation of source data
- Mission/flight set-up
- Debriefing

These processes are described in the following.

Digitisation of source data

After completing a flight, data collected from the plane must be converted to formats suitable for computer processing. Analogue data must be digitised and stored in appropriate formats.

- **Video.** Video recordings from the HUD and MED's must be digitised and converted to "mpg1" format.
- **Discrete flight path information.** Flight path information consisting of at least position (time, latitude, longitude, height) and optionally orientation (heading, pitch, yaw).
- **Event registrations.** Identification of events that occurred during the flight. These could be: Weapon-release, radar lock-on etc.
- **Environment.** Stationary and moving objects which give important input to the flight debriefing. This could for example be location of a SAM site.

Mission/flight Set-up

The purpose of the mission/flight set-up phase is to arrange the source data into logical units such as flights and missions. For example, a *flight* is a container for all data relating to a flight including; name of the pilot, identification of the plane, the videos recorded from the plane and the flight path data from the plane.

Data is arranged in a hierarchical structure:

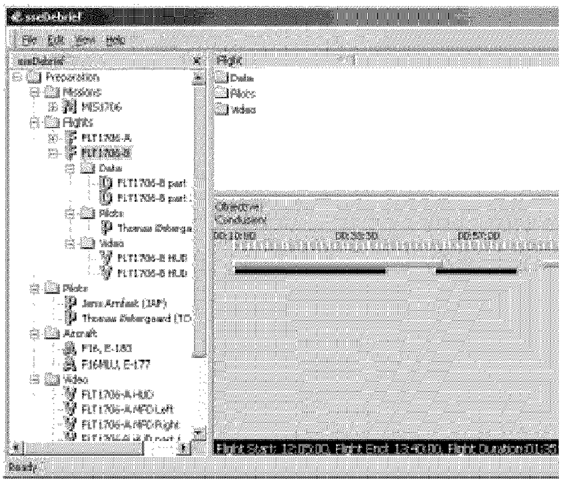

Figure 1: Data structure

The different types of data/files should be read as follows:

- **Mission.** A mission defines a collection of related flights. A debriefing typically involves several flights.
- **Flight.** A flight defines the pilot, the plane, a set videos recorded from the plane and flight path recording from the plane.
- **Pilot.** Defines the characteristics of a pilot
- **Plane.** Defines the characteristics of a plane/aircraft. Aircraft type/model, visual representation

- **Video.** Defines video recording from a plane (related to a plane). Includes start and stop time for the video.
- **Data.** Defines flight paths.

Debriefing
A debriefing is concentrated around a mission.

The screen is divided into five sections as displayed in Figure 2. Four of the sections are dedicated to displaying video and/or the 3D synthetic environment. The remaining section is dedicated to the timeline and playback controls.

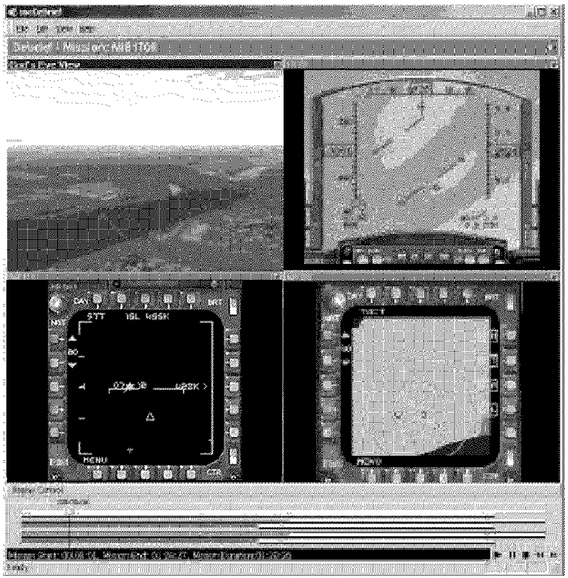

Figure 2: Division of screen in debriefing mode

The user can make use of following functionality:

- **3D syntetic environment:**
  - God's-eye view
  - Follow mode
  - Free movement
- **Video-playback:**
  - On/off
  - Sound
- **Play-back control:**
  - Play
  - Fast forward
  - Reverse
  - Slow-motion
  - Single step
  - Search (time, event)
- **Pop-up time based annotations/Attachments on:**
  - Data
  - Audio/Video
  - Flight
  - Mission
- **Computed "annotations":**
  - Speed, Height
  - Distance
  - Radar coverage
- **Information layers (on/off toggles)**
  - Flights

Combining commercial off the shelf (COTS) technology with military requirements

To reduce cost and improve the usability and learning process, Through studies of a range of commercially available products, we have experienced that today's COTS products basically cover all given requirements to a debriefing system.

COTS Hardware
The PC market, driven by the requirements set by the entertainment industries "need" to produce more and more realistic games, produces high-performance affordable systems. Current state-of-the-art entertainment PCs are capable of delivering the high performance in the areas essential to 3D graphics and video applications. The essential areas are:

- Processing power — Fast processors are required to handle movements through the 3D-terrain model. Multiple processors are recommended.
- Main storage — Memory (RAM) is essential to store the 3D-terrain in use.
- Mass storage — Harddisk space is needed to store digitised videos and 3D synthetic terrain. Today mainstream harddisks are both fast and has large capacities.
- 3D graphics — A 3D accelerated graphics adapter is essential to produce 3D synthetic environments at suitable resolution and frame rates. The entertainment industry drives the need for 3D graphics performance. Current and next generation consumer 3D graphics systems are powerful enough to drive the 3D synthetic environment.

COTS Software
We have found that most of the necessary software for the debriefing system is available in different COTS products, which can be acquired within a reasonable price or directly downloaded from the Internet. By using these products we also make it easier for the user to learn to use the system. We decided early in the project to use Windows 2000 instead of Windows NT. The reason for this is that Windows 2000 can handle concurrent use of video and 3D-graphics.

Experiences
We have spent many hours searching for relevant software products on the Internet and other places. We have certainly gained benefit from these efforts. Generally speaking there is COTS technology available — especially from the entertainment industry — to support and develop a range of high-tech, virtual reality training systems. Our task has almost been reduced to integration of already well-proven and tested blocks of

software code. However, it must be stressed out that the main challenge was to make the individual products work together.

Perspective

The debriefing system has great extension possibilities. As an example, the air force's simulators could use the debriefing system for evaluation of the simulation training. By doing so, simulation and use of the debriefing system will become an integrated part of the general simulator training. Consequently, the possibility for evaluating "what if" situations (situations where a training scenario is evaluated against *new* actions) would become a reality. An existing training scenario that has been practised and debriefed in the debriefing system could provide input to the simulator. The simulator could then fly with the scenario, and what-if situations could be simulated in order to evaluate the effect.

The interaction with other ground systems, such and C3 and Mission Planning Systems, are further areas to look into. As an example, the debriefing system could be used to build an Airspace Co-ordination Order (ACO): With a "magic wand" the operator could guide and virtually draw a route through the 3D landscape. An F-16 fighter could then use the ACO generated. When the mission is completed, the route planned and carried out could be compared in the debriefing system.

Another opportunity would be to investigate the debriefing facility in an interaction with other armed forces. As an example, the Navy's air combat system could be investigated and evaluated. One of the problems of the Navy in air combat is finding the optimal defence process, and the debriefing system may turn out to be useful.

The F-16 is equipped with a MUX-BUS interface. Through this interface much more information, e.g. weapon-release can be accessed. Recording these information and successively replay during the debriefing will give a much more detailed image of the flight.

The opportunities described above are just some areas where it may be possible to use the debriefing system. When the system is in operation, other opportunities are likely to appear, and technology will show us which.

Conclusions

We have developed a mission debriefing system that in principle covers the basic requirement and to some extend even exceeds these requirements. No dedicated software has been developed for use in this first generation of the system. The input to the debriefing system is not made especially for this purpose, but already available sources have been sufficient (a digitisation of the flight videos has though been necessary). Available COTS software and hardware has shown its value for this purpose, which means that the main task for us has been to integrate already available products and input. As integration is one of our company's main business areas, we are able to do this quite fast and therefore within an affordable price.

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